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Application number GB **0810155.2**

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2. Full name, address and postcode of the applicant or of each applicant *(underline all surnames)*:
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Patents ADP number *(if you know it)*: 8333072003

3. Title of the invention: An Improved Mist Generating Apparatus and Method

4. Name of your agent *(if you have one)*: Murgitroyd & Company

"Address for service" to which all correspondence should be sent. This may be in the European Economic area or Channel Islands (see warning note below) *(including the postcode)*
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AN IMPROVED MIST GENERATING APPARATUS AND METHOD

The present invention provides an improved apparatus and method for generating mists of very small droplets, which have been shown to be beneficial in a number of diverse fields. Examples of such fields include cooling, fire suppression and decontamination applications.

WO01/76764 discloses a mist generating apparatus which uses two fluids, primarily for use in fire suppression. In WO'764 an aerosol of first fluid droplets (i.e. droplets of a first fluid carried in a gaseous medium) is passed through a number of first fluid nozzles into a mixing zone. At the same time, a stream of gas is injected into the mixing zone upstream of the first fluid nozzles. The gas carries the first fluid droplets through an outlet nozzle which sprays the combined stream of first fluid droplets and second fluid from the apparatus. The purpose of WO '764 is to reduce the frictional forces which act on the droplets when they are sprayed into the atmosphere by carrying the droplets out of the nozzle on the gas stream.

WO '764 only uses the gas stream to carry the droplets out of the nozzle. The aerosol of first fluid droplets is created at an undisclosed location upstream of the WO '764 apparatus, and the apparatus itself does not apply any mechanism to further atomise the droplets of the first fluid in the aerosol. Consequently, the aerosol created upstream of the WO'764 apparatus dictates the size of the droplets sprayed from the apparatus, with the apparatus itself having no effect on the droplet size. A further limitation of the WO'764 apparatus is that it is difficult to achieve a homogenous mixture of droplets and gas. WO '764 relies on a single, annular stream of gas which is positioned radially outward of the first fluid passage and nozzles. This arrangement makes it highly unlikely that an effective distribution of first fluid droplets in the gas will be achieved. Such

limitations can cause unpredictable variations in droplet size and distribution very likely with the arrangement shown in WO '764.

It is an aim of the present invention to obviate or mitigate these and other disadvantages with the prior art.

According to a first aspect of the present invention, there is provided an apparatus for generating a mist, comprising:

at least one working fluid passage having an inlet in fluid communication with a supply of working fluid and an outlet;

a mixing chamber having a longitudinal axis and being in fluid communication with the working fluid passage outlet;

a plurality of transport fluid passages, each transport fluid passage having an inlet adapted to receive a supply of transport fluid and an outlet in fluid communication with the mixing chamber; and

a nozzle having an inlet in fluid communication with the mixing chamber, an outlet, and a throat portion intermediate the nozzle inlet and outlet, the throat portion having a cross sectional area which is less than that of either the inlet or the outlet.

The apparatus may further comprise a working fluid supply conduit having an inlet adapted to receive the supply of working fluid, wherein the working fluid passage inlet is in fluid communication with the supply conduit and the working fluid passage has a diameter which is less than that of the supply conduit.

At least one of the transport fluid passage outlets may be positioned closer to the longitudinal axis than the working fluid passage outlet.

The plurality of transport fluid passages may comprise an inner transport fluid passage co-axial with the longitudinal axis, and a plurality of outer transport fluid passages circumferentially spaced about the inner transport fluid passage.

The apparatus may comprise a plurality of working fluid passages, wherein the working fluid passages are circumferentially spaced about the inner transport fluid passage. The working fluid passages may be radially located between the inner transport fluid passage and the outer transport fluid passages. Alternatively, each of the working fluid passages may be located between a pair of the outer transport fluid passages, whereby the working fluid and outer transport fluid passages alternate circumferentially about the inner transport fluid passage.

The plurality of working fluid passages may comprise inner and outer working fluid passages, wherein the groups of inner and outer working fluid passages are both circumferentially spaced about the inner transport fluid passage, the outer working fluid passages being a greater radial distance from the inner transport fluid passage.

The working fluid and transport fluid passages may be substantially parallel to one another.

The at least one working fluid passage is substantially perpendicular to the longitudinal axis of the mixing chamber.

The working fluid supply conduit and the working fluid passage may be substantially perpendicular to one another.

According to a second aspect of the present invention, there is provided an apparatus for generating a mist comprising:

a body having a first end in which a working fluid inlet and a transport fluid inlet are defined and a second end in which a chamber is defined, the chamber having a first end in fluid communication with the working and transport fluid inlets and a second end which is open;

a first insert adapted to be received within the open end of the chamber, the first insert defining at least one working fluid passage in fluid communication with the working fluid inlet, and a plurality of transport fluid passages in fluid communication with the transport fluid inlet;

a second insert adapted to be received in the chamber between the first insert and the open end of the chamber, wherein the second insert defines a nozzle having a throat portion of reduced cross sectional area, and wherein the first and second inserts define a mixing chamber between them which is intermediate the working and transport fluid passages and the nozzle; and

a locking member adapted to be received on the second insert and the second end of the body so as to secure the first and second inserts in the chamber.

According to a third aspect of the present invention, there is provided a method of generating a mist, comprising the steps of:

supplying a pressurised working fluid to at least one working fluid passage;

introducing a supply of transport fluid into a mixing chamber downstream of the working fluid passage, thereby creating a turbulent zone within the mixing chamber;

atomising the working fluid by injecting a stream of working fluid from the working fluid passage into the mixing chamber;

directing the transport fluid and atomised working fluid from the mixing chamber towards a nozzle throat portion having a reduced cross sectional area;

accelerating the transport fluid through the nozzle throat portion, whereby the accelerating transport fluid imparts a shear force on the atomised working fluid and further atomises the working fluid droplets; and

spraying the transport fluid and atomised working fluid from a nozzle outlet having a greater cross sectional area than the nozzle throat.

The mixing chamber has a longitudinal axis, and a portion of the transport fluid may be introduced into the mixing chamber at a position which is closer to the longitudinal axis than that at which the working fluid is introduced.

A portion of the transport fluid may be introduced into the mixing chamber via an inner transport fluid passage which is co-axial with the longitudinal axis, and the remainder of the transport fluid may be introduced via a plurality of outer transport fluid passages circumferentially spaced about the inner transport fluid passage.

The working fluid may be atomised by passing the working fluid through a plurality of working fluid passages which are circumferentially spaced about the inner transport fluid passage. The working fluid passages may be radially positioned between the inner transport fluid passage and the outer transport fluid passages. Alternatively, each working fluid passage may be positioned between a pair of outer transport fluid passages, whereby the working fluid and outer transport fluid passages alternate circumferentially about the inner transport fluid passage.

A preferred embodiment of the present invention will now be described, by way of example only, with reference to the accompanying drawings, in which:

Figure 1 is a longitudinal section through a mist generating apparatus; and

Figure 2 is an end view of the apparatus shown in Figure 1.

The mist generating apparatus shown in Figure 1 and generally designated 10 is made up of four main components. The first component is a generally cylindrical body 20 having first and second ends 22,24. A neck portion 26 projects longitudinally from the first end 22 of the body 20. At the second end 24 of the body is a chamber 28 which is open at the second end 24 of the body 20 and adapted to receive other components of the apparatus 10, as will be described below. Extending longitudinally through the body 20 is a first supply conduit, or transport fluid supply conduit, 30. The transport fluid conduit 30 has an inlet 32 in the neck portion 26 and an outlet 34 which opens into the chamber 28. The transport fluid conduit 30 has a diverging profile, where the cross sectional area of the conduit 30 increases as it extends through the body 20 from the inlet 32 towards the outlet 34. A second supply conduit, or working fluid supply conduit, 36 is also provided in the body 20 and extends through a side wall of the body 20. The working fluid supply conduit 36 has an inlet 38 on the exterior of the body 20 and an outlet 40 which opens into the chamber 28. Thus, the transport and working fluid supply conduits 30,36 are substantially perpendicular to one another. The neck 26 and/or the inlet 34 are adapted so they can be connected to a source of transport fluid (not shown), while the working fluid inlet 38 is adapted so that it may be connected to a source of working fluid (not shown). The second end 24 of the body 20 has a projecting lip portion 42 of reduced

diameter, where at least a part of the outer surface of the lip 42 is provided with a thread (not shown).

Two other components forming part of the apparatus are a first fluid distribution insert 50 and a second nozzle insert 70, which are adapted to be located within the chamber 28 of the body 20. The first and second inserts 50,70 are shown in position within the chamber 28 in Figure 1. The first insert 50 can also be seen in the end view of the apparatus 10 shown in Figure 2, where the second insert has been removed for illustrative purposes.

The first insert 50 is a generally cylindrical insert which is I-shaped when viewed in a vertical section, as clearly seen in Figure 1. In other words, the insert 50 is widest at its outer periphery with the central portion of the insert 50 having a reduced width by comparison. The insert 50 has a first end face 52 and a second end face 54. Each of the end faces 52,54 of the insert 50 has an annular groove 56,57 extending about the circumference of the outer periphery of the insert 50. Located in each of the annular grooves 56,57 is an O-ring seal 58,59.

Because the insert 50 has an I-shape when viewed in a vertical section, the first and second end faces 52,54 of the insert 50 have first and second concave cavities 53,55, respectively, formed therein. Extending longitudinally through the insert 50 and fluidly connecting the first and second cavities 53,55 are a plurality of first passages, or transport fluid passages, 60a,60b. An inner first passage 60a is located in the centre of the insert 50 such that it is co-axial with a longitudinal axis L shared by the insert 50 and the assembled apparatus 10. The outer first passages 60b are circumferentially spaced about, and substantially parallel with, the inner first passage 60a and the longitudinal axis L.

The insert 50 also has an outer surface 62 in which a channel 64 is formed. The channel 64 extends around the entire circumference of the insert 50. Extending radially inwards through the insert 50 from the channel 64 are a plurality of working fluid supply conduits 66. The supply conduits 66 are substantially perpendicular to the first passages 60 and longitudinal axis L. The supply conduits 66 extend radially inwards through the insert 50 in the circumferential spaces provided between the outer first passages 60b. The supply conduits 66 allow fluid communication between the channel 64 and a plurality of second passages, or working fluid passages, 68a,68b located at the inner end of the conduits 66. The second passages are divided into two groups whereby there are a plurality of inner second passages 68a and a plurality of outer second passages 68b. Each of the second passages 68a,68b is substantially parallel with the longitudinal axis L and the first fluid passages 60a,60b and thus substantially perpendicular to the supply conduits 66. The second passages 68a,68b have a substantially constant diameter which is preferably less than that of the supply conduits 66. The inner and outer second passages 68a,68b are circumferentially spaced about the inner first passage 60a and axis L, with the outer second passages 68b being located radially outwards of the inner second passages 68a. The second passages 68a,68b are substantially perpendicular to the longitudinal axis L, as well as the first passages 60a,60b..

The relative radial and circumferential positions of each of the first and second passages can be best seen in Figure 2. From Figure 2, it can be seen that the second passages 68a,68b are circumferentially spaced so as to surround the inner first passage 60a, whilst the outer first passages 60b are circumferentially spaced so as to surround the second passages

68a,68b. It can also be seen in Figure 2 that the radial distance between the second passages 68a,68b and the inner first passage 60a and longitudinal axis L is less than the radial distance between the second passages 68a,68b and the the outer first passages 60b. The second passages 68a,68b are therefore positioned in close proximity to the centre of the apparatus.

The second nozzle insert 70 can be seen in position in the apparatus 10 in Figure 1. As with the first insert 50, the second insert 70 is generally cylindrical and shares the longitudinal axis L of the remaining components of the apparatus 10. The second insert has a nozzle 72 defined therein, the nozzle 72 having a nozzle inlet 74, a throat portion 76 and a nozzle outlet 78. The nozzle 72 is co-axial with the axis L and the throat portion 76, which is intermediate the inlet 74 and outlet 78, has a cross sectional area which is less than that of either the inlet 74 or the outlet 78.

The nozzle insert 70 has first and second ends having a first end face 71 and a second end face 73, respectively. A groove 80 is located in the outer surface of the insert 70 adjacent the first end. The groove 80 extends around the entire circumference of the insert 70 and an O-ring seal 82 is located in the groove 80. The nozzle insert 70 has a reduced diameter portion 75 adjacent the second end. The variation between the standard diameter of the insert 70 and the reduced diameter portion 75 creates an abutment face 77, which faces in the direction of the second end of the insert 70.

The final component of the apparatus 10 is a locking member 90, again shown in Figure 1. The locking member 90 is preferably in the form of a ring which has a first end 92 and a second end 94. The locking member 90 has a bore passing through it which is formed from first and second

portions 96,98. The first bore portion 96 is adjacent the first end 92 whilst the second bore portion 98 is adjacent the second end 94. The first bore portion 96 has a greater diameter than the second bore portion 98. The variation in diameter between the first and second bore portions 96,98 creates an abutment face 100, which faces in the direction of the first end 92 of the locking member 90. At least a part of the internal surface of the first bore portion 96 is provided with a thread (not shown). The second end 94 of the locking member 90 can be provided with one or more apertures 102 adapted to receive a suitable tool for securing the locking member 90 to the remainder of the apparatus 10.

The various components of the apparatus 10 as described above are assembled in the following manner. Firstly, the fluid distribution insert 50 is slid into the chamber 28 via the second end 24 of the body 20. The internal diameter of the chamber 28 and the external diameter of the insert 50 are such that a close fit is achieved between the insert 50 and the body 20. When the insert 50 is correctly positioned within the chamber 28, the first end face 52 of the insert abuts the outlet 34 of the transport fluid supply conduit 30 in the body 20. As a result, the outlet 34 of the transport fluid supply conduit 30 is in fluid communication with the first cavity 53 of the insert 50, and the second fluid supply conduit 36 is in fluid communication with the channel 64 of the insert 50. The O-ring seal 58 provides a sealing fit between the first insert 50 and the body 20.

Once the first insert is in position, the second insert 70 can be inserted into the chamber 28 via the second end 24 of the body 20. As with the first insert 50, the internal diameter of the chamber 28 and the external diameter of the second insert 70 are such that a close fit is achieved between the insert 70 and the body 20. When the second insert 70 is correctly positioned within the chamber 28, the first end face 71 of the

second insert 70 abuts the second end face 54 of the first insert 50. As a result, a mixing chamber sharing the longitudinal axis L is defined by the nozzle inlet 74 of the second insert 70 and the second cavity 55 of the first insert 50. Consequently, the body 20, first insert 50 and second insert 70 are now all in fluid communication with one another via the previously described cavities, passages and conduits defined within these components, as will be described in further detail below. The second of the O-ring seals 59 located in the second end face 54 of the first insert 50 provides a sealing fit between the first and second inserts 50,70.

Finally, once the first and second inserts 50,70 are located in their correct positions in the chamber 28 of the body 20, the locking ring 90 can be placed over the second end of the second insert 70. The threaded portions of the lip 42 of the body 20 and the first end 92 of the ring 90 cooperate with one another so that the ring 90 can be screwed into position by way of a tool (not shown) inserted into the apertures 102 in the ring 90. The ring 90 is screwed onto the body 20 until the respective abutment faces 77,100 of the second insert 70 and the ring 90 come up against one another. Once this has taken place, the first and second inserts 50,70 are firmly held in position, sandwiched between the body 20 and the locking ring 90.

As the assembly of the various components is complete, the manner in which the apparatus 10 operates can now be described. Initially, a transport fluid is introduced from a suitable source into the transport fluid supply inlet 32. There are a variety of fluids which would be suitable for use as the transport fluid, but in this preferred example the transport fluid is air. The transport fluid passes along the transport fluid supply conduit 30 in the direction of the arrow T into the first cavity 53 defined in the first insert 50. Once in the first cavity 53, the transport fluid separates into a

number of flow paths as it enters the inner and outer first fluid passages 60a,60b provided in the first insert 50. As the transport fluid flows leave the first fluid passages 60a,60b they enter the mixing chamber defined between the second cavity 55 of the first insert 50 and the nozzle inlet 74 of the second insert 70. The various transport fluid flows come into contact with one another in the mixing chamber, thereby creating a turbulent zone in the mixing chamber. The transport fluid enters the mixing chamber under high pressure but with a relatively low velocity.

At the same time as the transport fluid is being introduced into the transport fluid supply conduit 30, a working fluid is being introduced from a suitable source under high pressure into the working fluid supply conduit 36 provided in the body 20. As with the transport fluid, the working fluid can be a number of fluids but in this preferred example is water. As the working fluid passes through the working fluid supply conduit 36, it enters the channel 64 provided in the exterior of the first insert 50. The working fluid can then flow around the entire circumference of the first insert 50 via the channel 64, which lies between the body 20 and the first insert 50. As it flows around the channel 64, the working fluid enters the plurality of radial supply conduits 66 in the first insert 50 and flows inwards towards the longitudinal axis L of the apparatus. At the inner ends of the supply conduits 66, the working fluid turns through 90 degrees and enters the inner and outer second fluid passages 68a,68b. This 90 degree turn destabilises the working fluid, which enhances the atomisation of the working fluid in the mixing chamber, which will be further described below.

Once the working fluid reaches the outlets of the second fluid passages 68a,68b, a stream of working fluid is injected from each second passage 68a,68b into the mixing chamber. As the injected working fluid streams come into contact with the ambient gas in the mixing chamber, frictional

forces between the two lead to the atomisation of the working fluid streams, thereby forming droplets of working fluid. The turbulence generated by the transport fluid entering the mixing chamber ensures that the droplets created by this atomisation of the working fluid are spread throughout the mixing chamber. This is the first stage of the atomisation mechanism employed by the present invention.

The remaining stages of the atomisation mechanism occur in the nozzle passage 72 of the apparatus 10. Once the working fluid droplets enter the mixing chamber they are carried by the turbulent transport fluid into the nozzle inlet 74. The reduction in cross sectional area between the nozzle inlet 74 and the nozzle throat 76 leads to an acceleration of the transport fluid to a very high, preferably supersonic, velocity. This acceleration of the transport fluid leads to a large velocity difference between the transport fluid and the working fluid droplets. This difference in velocity causes a shearing force to be imparted on the droplets by the accelerating transport fluid, which leads to a further atomisation and reduction in size of the droplets as they pass through the throat portion 76 of the nozzle 72. This shearing action is the second stage of the atomisation mechanism.

The reduced size working fluid droplets leave the nozzle throat 76 at very high, and possibly supersonic, velocity. As previously described, the nozzle outlet 78 has a greater cross sectional area than the nozzle throat 76. Consequently, the high velocity transport fluid and the working fluid droplets being carried therein undergo an expansion as they flow from the throat portion 76 towards the outlet 78. This expansion stretches and expands the working fluid droplets, causing a further atomisation and further reduction in their size before they are finally sprayed from the nozzle outlet 78 in a dispersed phase as a mist. This expansion of the

droplets is the third stage in the atomisation mechanism employed by the present invention.

Providing a plurality of transport fluid passages allows the formation of a number of separate transport fluid flow paths into the mixing chamber. When these various transport fluid flows contact one another in the mixing chamber, a greater amount of turbulence is created in the mixing chamber. The enhanced turbulence ensures that the atomised droplets are kept separate from one another within the mixing chamber. Thus, the droplets are less likely to coalesce back into larger droplets once in the mixing chamber. Arranging the various passages so that the transport fluid outlets surround the working fluid outlets, whether in the radial or circumferential direction, achieves a more homogenous distribution of droplets in the mixing chamber and expansion section (i.e. post-throat portion) of the nozzle. This ensures that the third (expansion) stage of the atomisation process is as effective as possible.

When present, a plurality of working fluid passages allows a greater flowrate of working fluid to be atomised.

Positioning the working fluid passage outlets towards the outside of the mixing chamber can enhance atomisation by optimising a wall stripping mechanism. With wall stripping, a film of working fluid which attaches itself to the inner surface of the mixing chamber will be gradually atomised as the transport fluid flow strips droplets from the film of working fluid.

The transport fluid supply conduit, the transport fluid passages and the nozzle passage are relatively wide and have minimal restrictions therein. As a result, a particulate-laden fluid can be used as the transport fluid

without any concerns that the relevant passages will become blocked by the particulate matter contained in the transport fluid.

By forming the apparatus from only four components, the present invention provides a simplified manufacturing process. The individual components themselves are of a reduced complexity compared with existing apparatus, which is advantageous in terms of production costs. Additionally, as the two inserts are fitted in the body and held in place by the locking member, the machining tolerances required when manufacturing the components can be reduced.

Whilst preferable, the second fluid passages need not be located radially between the inner and outer first fluid passages. The second fluid passages could be located so that they are between pairs of the outer first fluid passages, so that the second fluid passages and outer first fluid passages alternate in the circumferential direction about the axis L. In other words, the outlets of the second fluid passages are surrounded in the circumferential direction by the outlets of the first fluid passages.

The second fluid passages may also be fluidly connected with the outer first fluid passages in the first insert such that atomisation commences within the second fluid passages upstream of the mixing chamber.

Each of the second fluid passages may include a turbulence-generation component therein. The component may take the form of a tapered edge inside the passage, for example.

Although the preferred embodiment of the apparatus described above has only one working fluid inlet in the body, there may be a plurality of working fluid inlets circumferentially spaced about the side wall of the body. Each

of the working fluid inlets may be in fluid communication with the channel extending about the circumference of the first insert.

In its simplest form, the apparatus of the present invention comprises a plurality of transport fluid passages and at least one working fluid passage which open into a mixing chamber and a nozzle downstream of the mixing chamber. This arrangement alone can provide one or more of the benefits listed elsewhere in this specification. Therefore, whilst the description of the preferred embodiment of the present invention above describes various groups of passages and their preferred radial and circumferential positions relative to one another, it should be understood that these combinations are not essential for the successful operation of the invention. Whilst the preferred embodiment of the present invention described above comprises a plurality of working fluid passages, the present invention is not limited to a number of working fluid passages. The present invention will provide one or more of the advantages listed herein so long as it has one or more working fluid passages. Furthermore, whilst the preferred embodiment has an inner transport fluid passage which is co-axial with the longitudinal axis L, the present invention is not limited to the inclusion of this inner transport fluid passage. The present invention will also be effective with transport fluid passages which are only circumferentially spaced around the longitudinal axis L.

As already stated in the detailed description of the present invention, the transport fluid is not limited to air. Other examples of suitable fluids are nitrogen, helium and steam. Similarly, water is not the only suitable working fluid which can be used with the invention. Other fluids which include additives such as decontaminants, surfactants or suppressants are also suitable for use as the working fluid.

These and other modifications and improvements may be incorporated without departing from the scope of the invention.

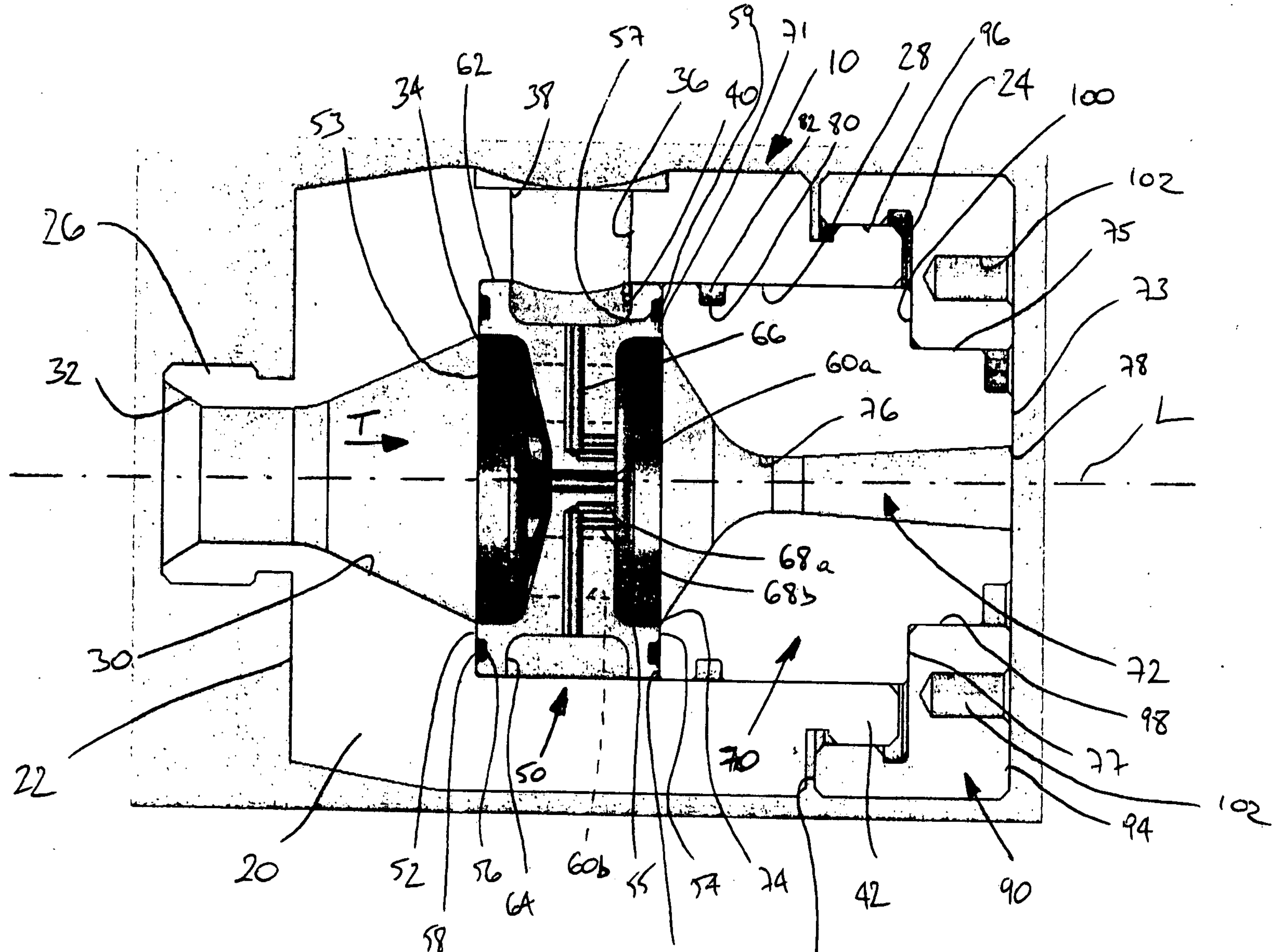

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Figure 1

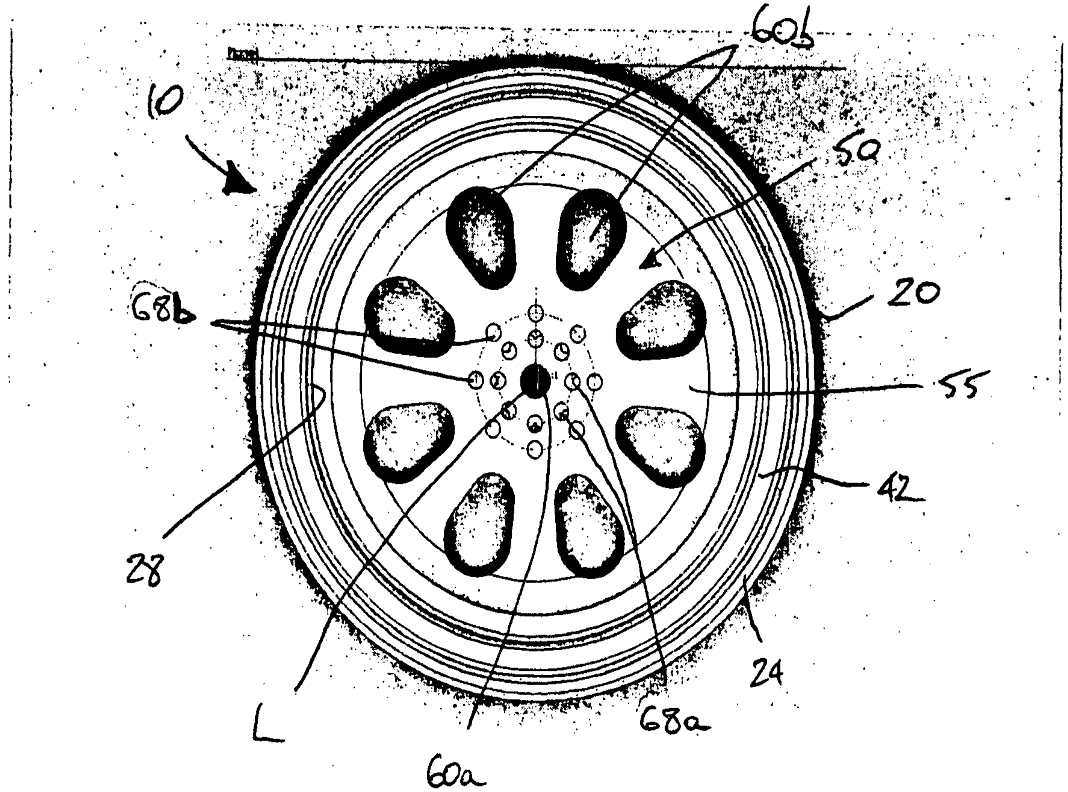

Figure 2